CHAPTER 1 DESIGN MANUAL OVERVIEW

1.1 INTRODUCTION

This manual sets forth stormwater management criteria and design methodology to be used by developers and their engineers and planners to control the peaks, volumes and quality of stormwater discharges from their developments. The manual provides developers, engineers and planners flexible tools to control the peaks, volumes and quality of stormwater discharges, all-important for maintaining stream stability and water quality. Use of this manual can lead developers to a unified up-to-date strategy for managing stormwater quantity and quality. This stormwater management can protect life, property, and the environment, and subsequently improve quality of life for the citizens of Columbia.

This manual is Columbia's initial attempt to prescribe state-of-the-art water quality and quantity protection practices for the Columbia area, based on current knowledge. The manual is intended to be a "living document" to be updated periodically as advances in water quality and quantity protection practices evolve. Future versions hopefully will reflect lessons learned from implementing the methods and practices currently recommended in this manual, particularly those involving water quality monitoring data, performance assessments and stream stability analysis.

1.2 MISSION STATEMENT

The mission of the City of Columbia Stormwater Management Ordinance and the Stormwater Management and Water Quality Manual is to protect the quality of life by limiting the amount of stormwater runoff as much as possible and by protecting those natural resources necessary for watershed health and integrity. This is primarily accomplished by mimicking natural hydraulics, hydrology and rainwater treatment. This mission statement is best accomplished by considering the following:

- Natural Streams are an asset to the community and should be regarded as such.
- The presence and protection of natural resources is fundamental to the quality of life of the citizens of Columbia and every facet of the stormwater system must recognize this.
- The best method of management is to preserve, restore and mimic natural processes.
- One of the best ways to manage stormwater runoff is to generate as little as possible and treat stormwater as near the source as possible.

1.3 BACKGROUND

Columbia has developed this manual based on the Mid-America Regional Council and the Kansas City Chapter of the American Public Works Association's 5600 Manual and Best Management Practices for Water Quality Manual as a proactive, integrated, watershed-based approach to stormwater management to (1) balance future development with environmental health and quality of life, and (2) comply with new water quality regulations such as the National Pollution Discharge Elimination System (NPDES) Phase II requirements. By implementing new policies and practices, Columbia seeks to reduce flooding, conserve water, improve water quality, protect wildlife habitat, and create community amenities. To that end, Columbia provides this document to assist developers, engineers and planners to create more environmentally sensitive site designs. Use of stormwater BMPs and practices outlined in this manual is one way Columbia hopes to achieve the goals of environmentally sound development and resource conservation.

The term "BMP" originated in the agriculture industry as a reference to practices, which reduce farmland erosion and improve crop yield. In the broadest sense, a stormwater BMP is any action or practice aimed at reducing flow rates and pollution concentrations in urban runoff; examples include site planning practices, public education efforts, open space preservation, pollution prevention practices, and engineered natural treatment systems. This manual describes two classes of BMPs: non-structural and structural. Non-structural controls minimize contact of pollutants with rainfall and runoff. Structural controls are facilities constructed for treating and controlling stormwater runoff.

This manual furnishes clear, understandable guidance for planning, designing and implementing the stormwater management facilities and best management practices. The manual provides design guidance with respect to controlling stormwater peaks, volumes and water quality, and provides effective methods by which these parameters can be addressed with a unified approach. Much of the foundation of the manual is based on established criteria such as Natural Conservation Service (NRCS) soil curve numbers and their hydrologic models. As previously mentioned, it is anticipated this manual will be a living document with beneficial amendments made as more information is available as to efficiency ratings of certain best management practices and other information becomes part of the mainstream stormwater management database of knowledge.

1.4 APPLICABILITY

For applicability requirements for use of this manual refer to Chapter 12A-87 of the City Code of Ordinances.

1.5 VARIANCES

The variance procedure is set out in the stormwater management ordinance in Chapter 12A-110 of the City Code of Ordinances.

1.6 DEFINITIONS

Best Management Practices (BMP): Activities, practices and procedures which control soil loss and reduce or prevent water quality degradation caused by nutrients, animal wastes, toxins, organics and sediment in the runoff. BMPs may either be structural (grass swales, terraces, retention and detention ponds, and others); or non-structural (disconnection of impervious surfaces, directing downspouts onto grass surfaces and educational activities).

Bioengineered Channel: A channel, which embodies biological, ecological, and engineering concepts to convey stormwater runoff, prevent soil erosion, control sedimentation, and provide wildlife habitat. The channel may be stabilized entirely with native materials or may selectively incorporate man-made structural materials.

Bioretention: Soil and plant-based stormwater management practices designed to filter runoff from developed communities by mimicking vegetated systems that naturally control hydrology through detention, filtration, infiltration, and evapotranspiration.

Bottomlands: Low-lying lands along a watercourse subject to frequent flooding.

Channel Lining: Includes any type of material used to stabilize the banks or bed of an engineered channel including, but not limited to, vegetation.

Channel Protection Detention: Detention designed to detain runoff in a way to prevent erosion of downstream channels.

City: City of Columbia

Contractor: The individual, firm, partnership, joint venture, or corporation contracting with the Owner for performance of the work described in these specifications and plans.

Controlled Area: That part of the surface area where peak discharges are controlled by a detention facility.

Curve Number (CN): A runoff coefficient developed in the U.S. Natural Resource Conservation Service (NRCS) family of hydrologic models by combining land use and one of four hydrologic soil types on a parcel of land.

Design Storm: The combination of rainfall depth, duration, and distribution of a hypothetical rainfall event with a given likelihood of occurring in any year.

Detention Facility: A storm water management facility controlling storm water runoff from a site or watershed. The allowable runoff specified for detention facilities in Chapter 6 is intended to manage maximum storm water release rates to minimize flooding and does not address impacts on downstream erosion, water quality or the environment.

Detention Storage: The volume occupied by water above the level of the principal spillway crest during operation of a stormwater detention facility.

Developer: Any person, partnership, association, corporation, public agency, or governmental unit proposing to or engaged in "development".

Development: 1) The improvement of property for any purpose involving building or construction; 2) Subdivision, or the division of a tract or parcel of land into two (2) or more parcels; 3) the combination of any two (2) or more lots, tracts, or parcels of property for any purpose; 4) the preparation of land for any of the above purposes; or, 5) land disturbance that requires the issuance of a *Land Disturbance Permit* in accordance with the provisions of Chapter 12A.

Director: The Director of Public Works

Dry Detention Facility: Any detention facility designed to permit no permanent impoundment of water.

Dry Swale: An open, vegetated, drainage channel or depression with an engineered soil matrix and underdrains designed to filter stormwater runoff.

Easement: Authorization by a property owner for the use by another for a specified purpose, of any designated part of the property.

Emergency Spillway: A device or devices used to discharge water under conditions of inflow that exceed the design outflow from the primary spillway detention facility. The emergency spillway functions primarily to prevent damage to the detention facility that would permit the sudden release of impounded water.

Engineer: See ‘Registered Professional Engineer.’

Engineered Channel: An open drainage channel, which has been explicitly designed to convey stormwater runoff in accordance with this manual and as approved by the Director.

Engineered Swale: An open drainage channel designed to convey and infiltrate the entire runoff volume from a Water Quality Storm.

Extended Detention Wetland: A land area that is permanently wet or periodically flooded by surface or groundwater, and has developed hydric soil properties that support vegetation growth under saturated soil conditions. It may have been engineered with adequate capacity to detain large storm flows.

FHWA: Federal Highway Administration.

Floodplain: A relatively level surface of stratified alluvial soils on either side of a watercourse, which is inundated during flood events.

Filter Strip: A grassed area that accepts sheet flow runoff from adjacent surfaces. It slows runoff velocities and filters out sediment and other pollutants. Filter strips may be used to treat shallow, concentrated, and evenly distributed storm flows.

First Flush: The quantity of initial runoff from a storm or snowmelt event that commonly contains elevated pollutant concentrations. Often the first flush contains most of the pollutants in drainage waters produced by the event.

Freeboard: The difference in elevation between the top of a structure such as a dam or open channel and the maximum design water surface elevation or high water mark. It is an allowance against overtopping by waves or other transient disturbances.

Grassed Channel: A broad, mildly sloped, open channel designed to convey stormwater runoff to a downstream point and to filter pollutants while doing so.

Hydrologic Soil Group (HSG): NRCS soil grouping according to runoff producing characteristics. The chief criterion is capacity of soil (absent vegetation) to permit infiltration. Soils are grouped from HSG A (greatest infiltration and least runoff) to D (least infiltration and greatest runoff).

Impact Stilling Basin: A pool placed below an outlet spillway and designed for reducing discharge energies in order to minimize downstream erosive effects.

Impervious Surface: A surface that prevents the infiltration of stormwater.

Improved Channel: Any channel changed by grading or the construction of lining materials as approved by the Director.

Incision: Adjustment of the channel bed elevation downwards, typically in response to some type of disturbance.

Increased Runoff: Increase in volume or peak flow of stormwater runoff.

Indigenous Plant: A plant native to this area prior to European settlement.

Infiltration: Percolation of water into the ground.

Infiltration System: A system allowing percolation of water into the subsurface of the soil. This may recharge shallow or deep groundwater.

Level of Service (LS): The level of water quality protection recommended for a development or provided by a postdevelopment stormwater management system. The LS requirement for the development is determined by the change in runoff from the predevelopment condition. The LS provided by the stormwater management system is determined by a combination of detention and water quality treatment.

Low-drop Structures: A step pool energy dissipation structure typically constructed out of rock or concrete with a design vertical drop of 2 feet or less per step.

Meander Amplitude: The linear distance between the apex of one meander and the apex of the next meander in a naturally curving stream.

Meander Length: The length measured along the thalweg of one complete waveform.

Meander Wavelength: The length of one complete waveform, measured as the straight-line linear distance along the valley between two analogous points on a waveform.

National Pollutant Discharge Elimination System (NPDES): Defined in Section 402 of the Clean Water Act, this provides for the permit system that is key for enforcing the effluent limitations and water quality standards of the Act. The Phase II Final Rule—published in the Federal Register on December 8, 1999—requires NPDES permit coverage for stormwater discharges from certain regulated, small, municipal, separate storm sewer systems (MS4s) and from land areas between 1 and 5 acres disturbed by construction.

Native Species: Plant and animal species that exist in the region where they have evolved.

Natural Stream: Any river, creek, channel, or drainageway that has an alignment, bed and bank materials, profile, bed configuration, and channel shape predominately formed by the action of moving water, sediment migration, and biological activity. The natural channel's form results from regional geology, geography, ecology, and climate.

Open Channel: A maintained earthen or lined waterway with an open water surface as approved by the Director.

Ordinary High Water Mark: A line on the bank established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.

Owner: The owner of record of real property.

Pervious Pavement: A special type of pavement that allows water to infiltrate the surface layer and enter into a high-void, aggregate, sub-base layer. The captured water is stored in the reservoir layer until it either infiltrates the underlying soil strata or is routed through an underdrain system to a conventional stormwater conveyance system.

Plans: The approved plan drawings, profiles, typical cross-sections, working drawings, etc., and exact reproductions thereof, which show the location, character, dimensions, and details of the work to be done.

Point bars: Depositional features generally occurring on the inside of stream bends and opposite cut banks.

Pollutant: Anything, which causes or contributes to pollution. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes, yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, articles, and accumulations, which may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; including but not limited to sediments, slurries and concrete rinsate and noxious or offensive matter of any kind.

Pools: A deep reach of a stream. Often the reach of a stream between two riffles; a small and relatively deep body of quiet water in a stream or river.

Predevelopment: The time period prior to a proposed or actual development activity at a site. Predevelopment may refer an undeveloped site or a developed site that will be redeveloped or expanded.

Primary Outlet Works: A device such as an inlet, pipe, weir, etc., used to discharge water during operation of a storage facility under the conditions of the 1% storm or more frequent event.

Principal Spillway: A device such as an inlet, pipe, or weir used to discharge water during operation of the facility under conditions of the design storm.

Principal Stream: Stream Segments included in FEMA Flood Insurance Studies where the limits of the 1% floodplain and 1% base flood elevations have been determined.

Rain Garden: A small depression planted with native wetland and prairie vegetation, rather than a turfgrass lawn, where runoff collects and infiltrates. Rain gardens are most often used in residential areas.

Registered Professional Engineer: A licensed engineer who is registered with and authorized to practice engineering within Missouri.

Riffles: Shallow rapids in an open stream, where the water surface is broken into waves by obstructions such as natural channel armoring or bedrock outcrop wholly or partly submerged beneath the water surface.

Riparian Buffers: Bands of native herbaceous and woody vegetation along ephemeral, perennial and intermittent streams and open bodies of water. Buffers have three primary benefits. Riparian Buffers improve stream stability through mechanical and hydrological (via evapotranspiration) reinforcement of the streambanks. In addition to providing physical stability, the soils, plants and microorganisms capture and treat sediment and other pollutants in surface runoff water before these enter the adjoining surface waterbody. Buffers improve water quality and habitat by shading the stream and providing the leaf detritus necessary for beneficial aquatic life.

Riparian Zone: The vegetated band along the fringe of a stream or other water body.

Sand Filter: A self-contained bed of sand used to treat wastewater or diverted stormwater runoff; the water subsequently is collected in underground pipes for additional treatment or discharge.

Sediment Storage: The volume allocated to contain accumulated sediments within a detention facility.

Site: A tract or contiguous tracts of land owned and/or controlled by a developer or owner. Platted subdivisions, industrial and/or office commercial parks, and other planned unit developments shall be considered a single site. This shall include phased development where construction at a tract or contiguous tracts of land may occur in increments.

Storm: A rainfall event used for design, which is defined by the probability such an event, will be equaled or exceeded in any one year. When designing in accordance with these criteria, the storm event probabilities used are: 1%, 2%, 4%, 10%, 50% and 100%.

Storm Drainage System: All of the natural and man-made facilities and appurtenances such as ditches, natural channels, pipes, culverts, bridges, open improved channels, swales, street gutters, inlets, and detention facilities, which serve to convey surface drainage.

Stormwater Detention Facility: Any structure, device, or combination thereof with a controlled discharge rate less than its inflow rate.

Stormwater Management Facilities: May also be referred to as Structural Treatment Practices (STPs) and includes measures, primarily structural, which are determined to be the most effective, practical means of preventing or reducing point source or non-point source pollution inputs to stormwater runoff and subsequently into water bodies. These facilities are also used to control volume and peak rates of runoff from developing and redeveloping sites.

Streams: See "Natural Streams"

Swale: an engineered channel conveying stormwater from more than two lots; often the property owner maintains the swale but an easement is required when requested by the City.

Thalweg: The deepest part of a channel cross-section. The dominant thread of stream flow creates the thalweg.

Topsoil: Fertile, friable soil of uniform quality and consisting of the soil series A horizon, without a mixture of subsoil materials or soil series B horizon, and shall be reasonably free from materials such as hard clods, stiff clay, hardpan, partially disintegrated stone, large stone or any other impurities. Topsoil shall be reasonably free from grass, roots, or debris, which are considered to be harmful to plant establishment and growth.

Total Suspended Solids (TSS): Matter suspended in stormwater excluding litter, debris, and other gross solids exceeding 1 millimeter in diameter.

Tributary Area: All land draining to the point of consideration, regardless of ownership.

Treatment Rating (TR): A relative ranking of a BMP's stormwater treatment based on actual or assumed water quality benefits.

Treatment Train: The series of BMPs (or other treatments) used to achieve biological and physical treatment efficiencies necessary for removing pollutants from stormwater (or other wastewater flows).

Tree Preservation: Maintenance of existing trees and shrubs in a healthy and undamaged condition.

Uplands: Lands elevated above the floodplain that are seldom or never inundated.

Value Rating (VR): The assumed water quality improvement value of a cover type or BMP, based on its water quality treatment efficiency and ability to retain stormwater.

Water Quality: The chemical, physical, and biological characteristics of water. This term also can refer to regulatory concerns about water's suitability for swimming, fishing, drinking, agriculture, industrial activity, and healthy aquatic ecosystems.

Water Quality Storm: The storm event that produces less than or equal to 90 percent stormwater runoff volume of all 24-hour storms on an annual basis.

Water Quality Volume (WQv): The storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. It is calculated by multiplying the Water Quality Storm times the volumetric runoff coefficient and site area.

Watershed: All the land area that drains to a given body of water (also described as a basin, catchment, and drainage area).

Waveform: A complete cycle of two channel bends in opposite directions.

Wet Detention Facility: A detention facility that is designed to include permanent storage of water in addition to the temporary storage used to control discharge rates from the facility.

Wet Pond: A constructed system with sufficient capacity to detain flood volumes and to store the WQv in a permanent pool.

Wetland Treatment System: A stormwater or wastewater treatment system consisting of shallow ponds and channels vegetated with aquatic or emergent plants. This system relies on natural microbial, biological, physical, and chemical processes to treat stormwater or wastewater.

Work: Work shall mean the furnishing of all labor, materials, equipment, and other incidentals necessary or convenient to the successful completion of the project.

1.7 GOALS AND OBJECTIVES

The overall goal of this manual and the Stormwater Management Ordinance is to mitigate and reduce the environmental impact of increased stormwater runoff due to development, to control large water quantities produced by developing watersheds and to minimize quality impairment of runoff from impacted areas. This goal is accomplished through this manual by combining water quantity and water quality management using much of the existing natural system to maintain current conditions and prevent further deterioration of streams in the watershed.

Peak flows and overall quantity of stormwater runoff can be maintained after development, possibly reduced where conditions allow. Stormwater management facilities can regulate peak flows and assist the BMPs in improving stormwater quality by mitigating extreme Ph values and assisting removal of sediment, petroleum-based materials, biochemical oxygen demand, metals, bacteria, nutrients, toxic organic compounds and other substances which may be present in harmful concentrations.

This manual sets out the basic goals for all developments to maintain pre-development peak flows, runoff volumes and water quality. In other words, developments should not increase the velocity or quantity of water or the amount of pollutants leaving the site, essentially mimicking pre-existing hydrology. In order to accomplish this, the four basic water resource protection goals need to be addressed on each development site. These four water resource protection goals are: flood control, channel protection (stability), groundwater recharge, and finally, pollutant removal.

1.8 PRINCIPALS OF STORMWATER QUANTITY

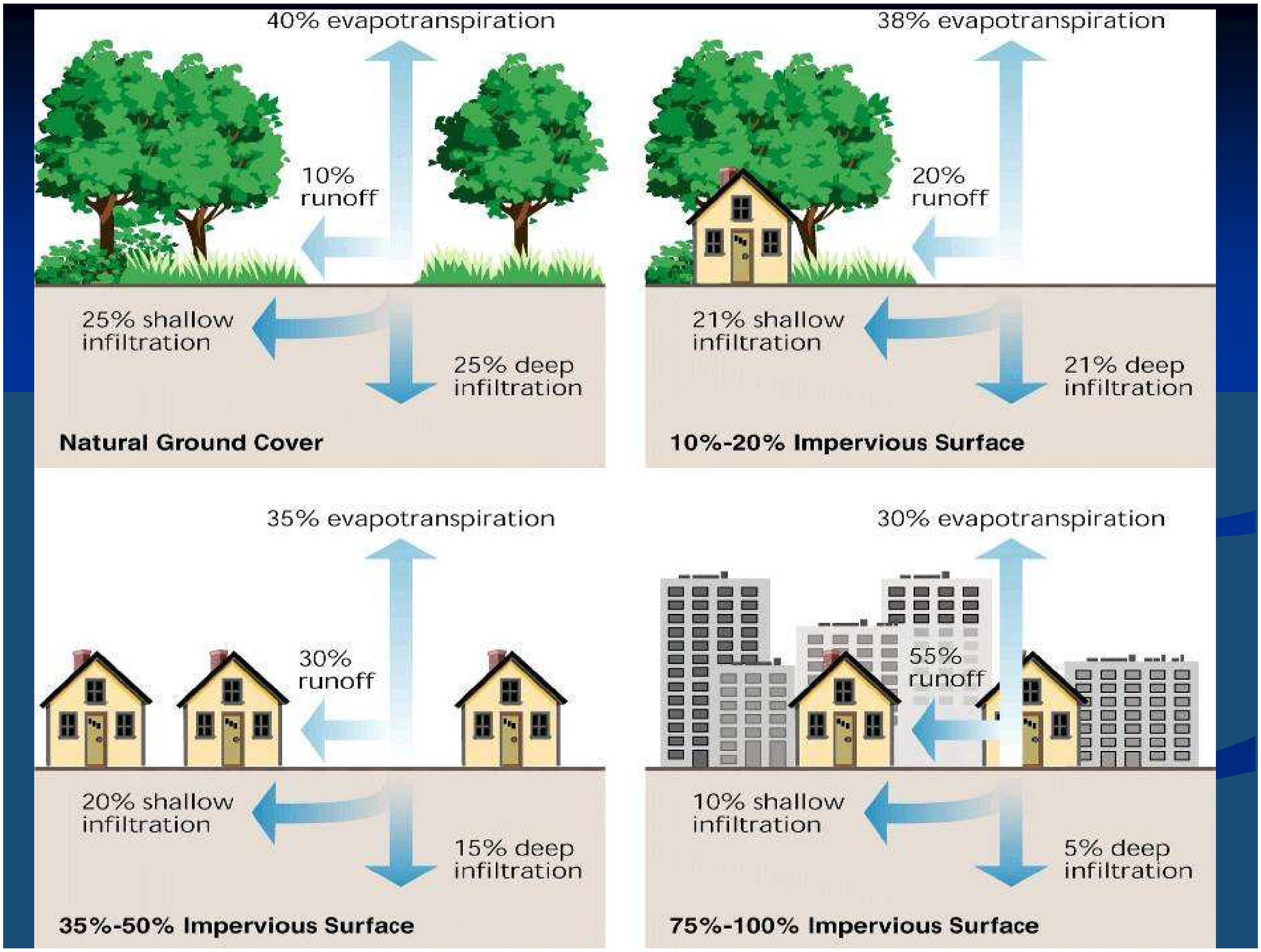
The hydrological effects of urbanization include a disruption of the natural water balance with increased flood peaks, increased stormwater runoff (volume), more frequent flooding, increased bankfull flows, and lower dry weather flows. This flow regime, often referred to as urban hydrology, is detrimental to the receiving streams in a developing watershed and commonly results in highly degraded channels with heavy sediment loads and reduced water quality. This manual provides guidance and direction through the use of stormwater management practices to control and minimize the impact of urbanization on the receiving streams.

Channels respond to increases in flow volumes and more frequent recurrence by altering width, depth, velocity, suspended load, meander radius, wavelengths and pool and riffle. Historically, detention and retention structures have been constructed to address these impacts (degradation) to streams. However, previous efforts have addressed larger storm events while allowing smaller events (less than the 50% storm event) to be handled on a pass-through basis. Experience has shown that even limiting the 50% storm event post-construction runoff to the 50% storm predevelopment runoff peak does not provide stream protection. Numerous studies have concluded the increased frequency and duration of these post-construction 50% storm events do significant damage to the receiving streams.

This manual addresses this issue by requiring the capture of the water quality volume storm for treatment, as well as requiring the 100% storm event pre- and post-development peak flows to be matched. Additionally, water quality BMPs such as bio-retention areas and dry cells serve to increase times of concentration for the post-development settings and provide some water quantity benefits in the post-development runoff hydrograph for calculation for overall detention requirements and watershed timing.

Stormwater volume control is more difficult to accomplish but practices such as infiltration (undisturbed areas with natural vegetation), evapotranspiration, short-term detention or retention, and establishment of artificial or induced baseflows are strategies which can be used successfully to reduce the impact of increased volume on the receiving streams. See Figure 1.8 below:

Figure 1.8



Source: EPA Fact Sheet. EPA 841-F-03-003

1.9 PRINCIPALS OF STORMWATER QUALITY

This manual requires certain water quality goals and provides tools for meeting these goals. The water quality goals and tools are based on several basic water quality concepts. Stormwater management proceeds from thorough site analysis to planning and to site design, and is unique for each site and development project. Proposed design in a stormwater management system is sensitive to site characteristics including slopes, soils and cover types, infiltration capacity, and detention. These characteristics can be preserved, restored and imitated through stormwater management techniques aimed at providing optimum site runoff water quality. Additional water quality BMPs may be applied for further reduction of pollutants in runoff where water quality goals cannot be achieved through site design alone.

Section 1.7 recommends stormwater management goals for Columbia. These goals are the basis for Columbia's stormwater management program. The goals cover both stormwater quantity and quality management, and provide options for various watershed conditions and levels of stringency. Section 1.10 discusses water quality concepts used to develop this manual and how they apply to water quality BMPs that are applied to meet water quality goals. This section is not comprehensive – more detailed water quality information may be obtained from the following resources:

- Chapter 1 of the *2000 Maryland Stormwater Design Manual, Volume I* from the Maryland Department of Environment includes a good discussion of basic stormwater management concepts.

- *The Stormwater Manager's Resource Center* (www.stormwatercenter.net) is directed to practitioners, local government officials, and others who need technical assistance on stormwater management issues.

Section 1.12 provides references and a brief description for several other BMP manuals.

1.10 WATER QUALITY CONCEPTS

Studies have shown that atmospheric deposition distributes most stormwater pollutants. A full range of pollutants is present in virtually all runoff—whether from yards, roads, or rooftops—because of this atmospheric redistribution. The pollutants are mobilized and impact surface water quality when rainfall produces runoff that carries the contaminants into surface waters. For this reason, impervious surfaces are the major source of stormwater pollutants in urban areas (Claytor and Schueler 1996). Runoff volumes and peak velocities are determined primarily by the site's cover type and soils, and other factors such as slope, distance, and existing drainage features (USDA 1986). Runoff quantity and water quality are linked, and this linkage forms the basis for this manual.

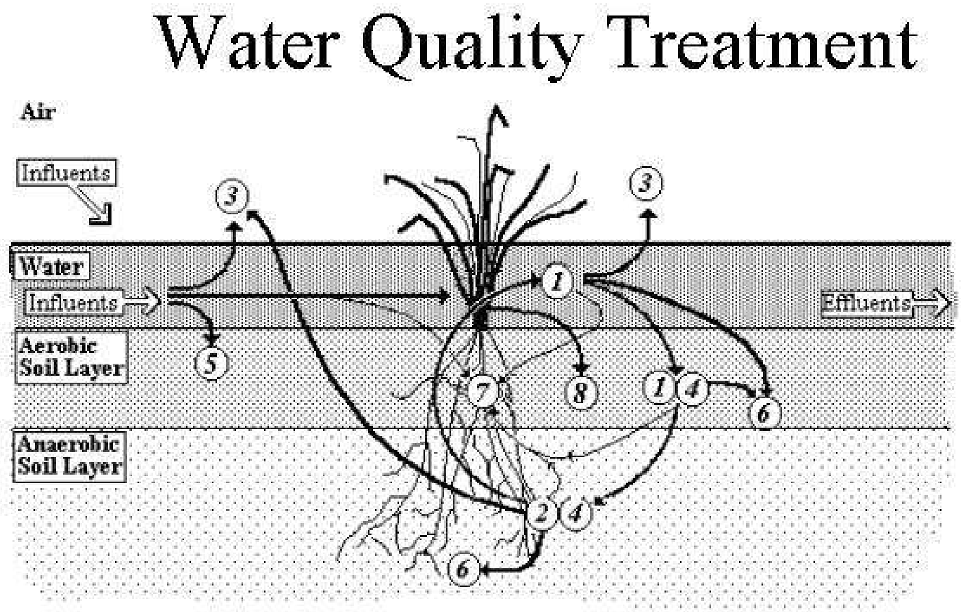
The first step in water quality management is to maintain or reduce the amount of runoff generated within a watershed. Treatment is then applied to the remaining runoff to remove some of the pollutant load. BMPs are the key to both approaches, described below.

Preserving a site's infiltration capacity is a relatively inexpensive non-structural measure to reduce runoff rates, volumes, and pollutant loads. Stormwater runoff rates and volumes and water quality are influenced heavily by infiltration capacity (USDA 1986; Claytor and Schueler 1996). Urbanization shortens a watershed's response to precipitation mainly by reducing infiltration and decreasing travel time. An impervious surface decreases travel time by preventing infiltration and speeding runoff. Furthermore, faster runoff velocities reduce the opportunity for pollutants to settle out or be removed by natural processes.

Most urban areas are only partially covered by impervious surfaces, however, and natural infiltration rates to underlying soils are influenced primarily by soil type and by plant cover. Any disturbance of a soil profile and cover type can change infiltration characteristics significantly (USDA 1986). Site designs can preserve existing pervious surfaces (open space and vegetation, especially native species), incorporate pervious landscaping and vegetated cover, and reduce and disconnect impervious cover. Pervious cover, and especially vegetation, allows water infiltration that minimizes runoff, erosion, and potential for downstream pollution. Vegetation helps reduce erosion and filters sediment and other pollutants from stormwater runoff by creating a natural buffer to reduce the velocity of surface water. Native vegetation and open space provide aesthetic and habitat benefits. Site development practices also can protect soils from compaction and restore high-quality native soil characteristics. Appendix A discusses non-structural BMPs in considerable detail.

Stormwater quality can be improved significantly by treating the remaining runoff volumes with structural BMPs. Structural BMPs are designed to provide two factors: 1) infiltrate and reduce the amount of runoff, and/or 2) to filter and detain runoff to reduce discharge velocities and remove pollutants. Infiltration systems represent an example of the former, while bioretention areas (vegetated depressions designed to collect and treat runoff through an engineered matrix of soils and plant roots) represent an example of a filtration practice. As shown in Figure 1.10 below, filtration and detention BMPs remove pollutants by several processes, including physical settling and filtering by plants and soil media, aeration, adsorption onto soils, and biological processes in the root zone.

Figure 1.10
Natural Treatment Processes



Notes:
Eastlick 2001

1. Oxidation
2. Reduction
3. Volatilization
4. Adsorption
5. Sedimentation
6. Precipitation
7. Plant Uptake
8. Peat Formation

Some practices can also be designed to serve both functions, such as by locating the underdrain 6” or so above the bottom of the bioretention cell. Appendix B includes descriptions and design criteria for several structural BMPs.

Not all runoff contains high concentrations of pollutants, however. The initial rainfall mobilizes pollutants that have built up on pervious and impervious surfaces. The pollutants are more concentrated in this “first flush,” and concentrations gradually diminish as rainfall continues. To be efficient and cost-effective, water quality BMPs must be sized and designed to treat this more concentrated runoff rather than the extreme flood events that are managed by conventional stormwater systems. The design storm for water quality BMPs is the water quality volume (WQv). The WQv is defined as the storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. WQv is a function of the Water Quality Storm, which is the storm event that produces less than or equal to 90 percent volume of all 24-hour storms on an annual basis.

The following section discusses application of non-structural and structural BMPs.

1.11 TREATMENT TRAIN APPROACH

A single BMP may not suffice to meet the stormwater management and design objectives for a development. The preferred approach for water quality improvement is a combination or series of stormwater BMPs called a "treatment train." This set of biological and physical treatments successively removes pollutants from stormwater flows. A treatment train also can reduce the physical volume of runoff, thus reducing stormwater management costs while improving water quality (Texas APWA 1998).

While many practitioners focus on engineered structural BMPs, a treatment train combines site development strategies, management and housekeeping practices, and engineered solutions. What is not imposed on a site or development can be more important than the applied engineered BMPs. This vital first step is called Site Fingerprinting. By this we mean that the designer accommodates the natural features and landforms. Site fingerprinting avoids disturbance of riparian areas, steep slopes or highly erodible soils. Site fingerprinting also minimizes grading and incorporates the land contours into the design. Avoidance is the best strategy to deal with most problems – the most cost-effective practice is to limit the generation of runoff by preserving or creating natural areas and vegetation that soak up precipitation, slow runoff, and filter sediment. Engineered solutions then deal with the remaining runoff volume most effectively at the source. Infiltration and filtration BMPs placed at the source also reduce runoff volumes and peak flows from smaller, more frequent storms (see Chapter 2 for a discussion of water quality and hydrology). Finally, what cannot be absorbed or treated at the source must be routed through larger BMPs for detention and treatment prior to discharge from the site. Pollution prevention is also applied so that contaminants are not released from a site where they can be picked up by runoff and carried into surface water bodies. Selection of treatment train components is based on a combination of local and state stormwater requirements, site characteristics, development needs, runoff sources, financial resources, and BMP characteristics (such as space requirements, design capacities, and construction and maintenance costs).

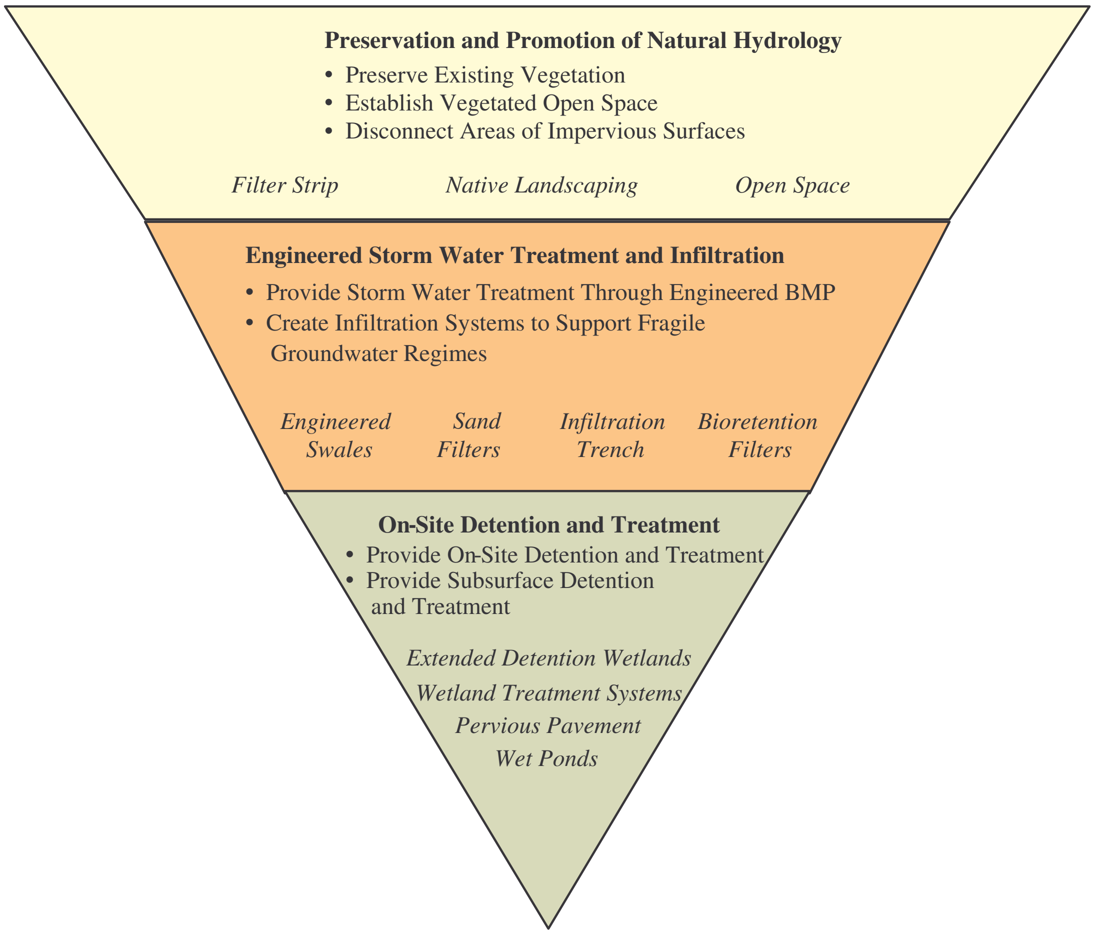
Before choosing a sequence of treatment practices, a planner must understand the site conditions and hydrological characteristics of the site's drainage area, and the requirements for water quality treatment. Developments are required to manage stormwater flow rate from the site in accordance with this manual. This manual includes guidelines for determining a development's approximate water quality impact and selecting an appropriate BMP package for the site and development. At a minimum, the predevelopment quality of the site must be maintained if possible. The procedure for ranking the predevelopment condition of the site and for selecting a BMP package, which will maintain that condition, is in Chapter 6. This procedure includes a method for determining how much treatment a development should include. Methods for determining site hydrology and for calculating the WQv are also described in Chapter 2.

Selecting a combination of practices, which meet basic requirements, is up to the developer and the site design team. The "right" treatment train best satisfies stormwater management requirements and the project goals, and it offers the most overall value for the development. Treatment train practices which generally follow the Hierarchy of Stormwater Best Management Practices (see Figure 1.11) usually provide the most benefit at the least cost and the greatest flexibility in addressing needs of the site design. The treatment train may include the following components, in order of preference:

- Site fingerprinting starting with preserved open space and natural vegetation, specifically avoidance of disturbance near water bodies
- Minimize disturbance during construction and impervious surfaces after construction
- Created open space with native vegetation
- Infiltration practices at the source of runoff—including rain gardens, infiltration trenches or similar BMP's
- Filtration systems at the source of runoff—such as vegetated filter strips, sand filters, or bioretention basins
- Engineered swales for capture at the source or conveyance between BMPs
- Detention structures such as channel protection detention basins, wetlands, extended detention wetlands, and wet ponds.

FIGURE 1.11.1

HIERARCHY OF STORM WATER BEST MANAGEMENT PRACTICES



The following examples illustrate hypothetical treatment trains for three types of sites:

Residential subdivision: (1) preserve native prairie remnant as common open space; (2) landscape with native vegetation; and (3) use dry swales to convey and treat runoff from landscaped streets and yards.

Commercial development: (1) establish native landscaping in and around buildings and parking areas to break up impervious areas; incorporate shade trees to cool parking lot runoff (2) use bioretention cells in parking lots.

Office park: (1) place filter strips around building downspouts and parking lots, leading to (2) infiltration basins; (3) use dry swales to treat runoff from streets and convey it to (4) a wet pond.

Three useful references for conservation development strategies are:

- Growing Greener Booklet from the National Lands Trust (http://www.natlands.org/planning/growgreen.html)
- Better Site Design: A Handbook for Changing Development Rules in Your Community (http://www.cwp.org/)
- Low-Impact Development Design Strategies – An Integrated Approach (http://lowimpactdesign.org/)

The following paragraphs discuss each stage of the treatment train in more detail. Appendices A and B discuss how to select and design BMPs.

Preserving and incorporating native areas into the design of the site or establishing open space with native vegetation is commonly the first stage of a treatment train. The more land left in an undisturbed state or returned to a natural state through native landscaping, the greater the water infiltration that minimizes runoff, erosion, and potential for downstream pollution. It is important to note that preservation is far more effective than recreation because many Central Missouri soils have dramatically reduced infiltration capacity once compacted. It takes many years or extensive soil reconditioning to reestablish the pre-disturbance soil performance.

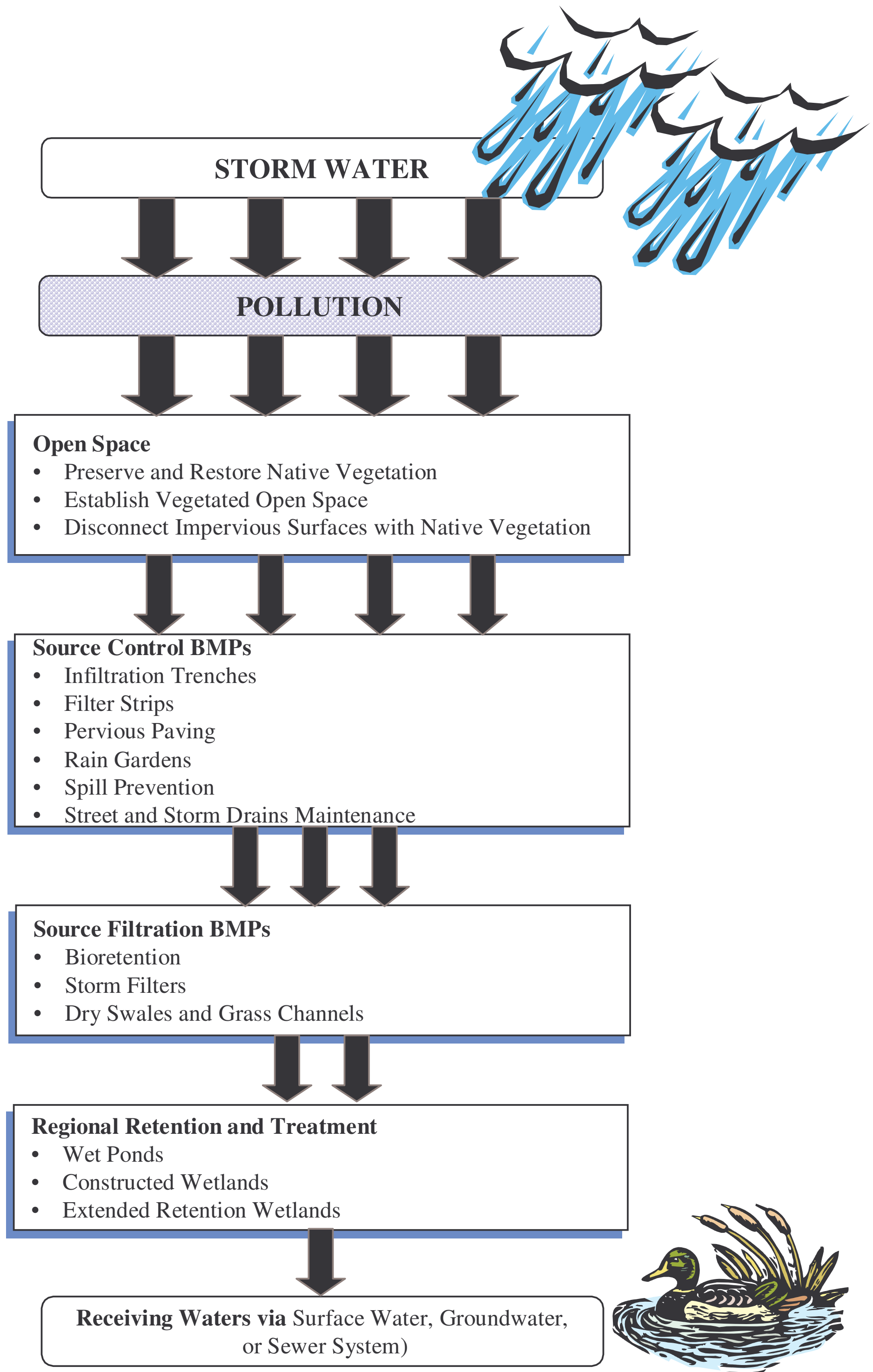
The proposed land use or site design may not allow for sufficient open space to manage all runoff from precipitation which falls on or runs onto a site. Runoff, which contacts pollutants (from rooftops, sidewalks, driveways, parking lots, roadways and so on), is most efficiently managed close to its origin. Often, the second stage of the treatment train controls runoff at its sources. Examples include pervious vegetated areas (such as lawns or specially designed filter strips around parking lots and buildings), infiltration trenches and basins, pervious pavement parking lots, and residential rain gardens (Texas APWA 1998). When considering lawns for treatment, it is important to note that conventional lawns are themselves sources of pollution because the intensive application of fertilizers, herbicides and pesticides can overwhelm any benefit provided by the filtration. Alternatives such as native Buffalo grass or No-Mow fescue mixes require little or no chemical input and provide the aesthetic benefits of a lawn with much better water quality performance. Source controls can maximally infiltrate and substantially reduce runoff, which contains pollutants (for example, runoff from the smaller storms such as the Water Quality Storm). In addition, reducing peak runoff rate—even from smaller rain events—decreases stress on downstream control facilities that consequently can be smaller. Peak reduction from reducing impervious surfaces or detaining these smaller events is a function of site and BMP design; it should be calculated and applied by the site engineer or stormwater planner as part of the design process.

Open space and infiltration practices alone may not suffice to manage all runoff from a site because of inadequate space, soils and geology, slopes, or other factors. Engineering filtration systems at or near the source of runoff is the next stage of the treatment train. Filtration systems route the most contaminated "first flush" of rainfall (the WQv) through an engineered natural filter. Examples of filtration systems include sand filters, bioretention, dry swales, and grassed channels (Center for Watershed Protection 2000b, Claytor and Schueler 1996). Note that by omitting underdrains, planners may use bioretention and sand filters for infiltration (see Appendix B). These practices also detain smaller rain events, as they are designed to treat the Water Quality Storm. The stormwater engineer or planner should estimate the maximum volume of detention available and required.

Devising stormwater detention practices is the last stage of the treatment train. Detention generally applies to large developments; it provides solutions for sites where space inadequacy precludes stormwater treatment closer to the source. Detention may be the preferred option where predevelopment site conditions are of low quality. "Wet" detention detains and manages releases from larger rainfall events—usually up to and including the 100-year return interval event — and includes a treatment component sized for the WQv. Many examples and designs are discussed in Appendices B and C.

Finally, proper maintenance and pollution prevention practices can limit stormwater runoff pollution further. Routinely cleaning and periodically refurbishing BMPs helps them function as designed. Maintenance practices (such as sweeping streets and parking lots) remove pollutants before rainfall can mobilize them. Surely many pollutants result from airborne emissions and deposits, but some chemicals enter surface water from spills and leakage from equipment (Claytor and Schueler 1996). Pollution prevention strategies can contain common sense practices not included in most treatment trains— containment barriers around chemical storage areas to confine potential spills, berms around fueling stations to prevent stormwater run-on, or vehicle and equipment maintenance to prevent leakage (Texas APWA 1998). Chapter 6 includes information on such practices. Figure 1.11.2 illustrates an elementary treatment train concept.

FIGURE 1.11.2
STAGES OF A TREATMENT TRAIN



1.12 SUMMARY OF BMP SELECTION METHODS

Chapter 6 presents the "Level of Service Method," a BMP selection method designed for Columbia based on nationally recognized research and practices. This is not the only BMP application procedure, however. A number of jurisdictions throughout the U.S. have adopted their own methods for implementing water quality principles into workable development ordinances and design criteria.

Water quality planners, engineers, and developers may want to consult other manuals and guidance on a case-by-case basis. A number of the better-known methods are described below:

- *2000 Maryland Stormwater Design Manual, Volumes I & II*. Maryland Department of Environment, Water Management Administration. October 2000.

  This State of Maryland publication specifies 14 mandatory performance standards that apply to any construction activity disturbing 5,000 or more square feet of earth. The manual provides selection guidance for pretreatment, non-structural BMPs, and structural BMPs designed to remove 80 percent of the average annual post-development total suspended solids load and 40 percent of the average annual post-development total phosphorous load. The redevelopment policy specifies a 20 percent reduction in impervious surface area below existing conditions. Where impractical due to site constraints, this manual requires the use of BMPs to meet the equivalent in water quality control of a 20% decrease in impervious surface area. Additional BMPs are provided for stormwater "hot spots" or highly polluting land uses. This text also includes a good discussion of basic stormwater management concepts.

- Minnesota Urban Small Sites BMP Manual. Metropolitan Council. July 2001.

  This manual provides voluntary BMP application and design guidance for small sites (less than 5 acres). The manual furnishes general siting and selection criteria, design guidance, and operation and maintenance recommendations for 40 BMPs—along with relative rankings of each based on treatment suitability, physical feasibility, and community acceptance.

- *Stormwater Management Manual, Revision #2*. The City of Portland, Oregon, Environmental Services Department. September 2002.

  The City of Portland requires that all development projects with over 500 square feet of impervious development footprint area, and all redevelopment projects redeveloping over 500 square feet of impervious surface, treat runoff from the additional impervious areas. Portland requires treatment and removal of 70 percent of total suspended solids (TSS) from runoff generated by a design storm up to and including 0.83 inches of rainfall over a 24-hour period. The manual provides a list of acceptable BMPs and simplified sizing and design guidance for each based on the impervious area treated. It also includes a performance-based BMP selection method for designing and customizing BMPs.

- *Urban Best Management Practices for Nonpoint Source Pollution*. Wyoming Department of Environmental Quality, Water Quality Division. February 1999.

  This text is a general reference for water quality principles, and for selecting and applying BMPs geared toward semi-arid climates.

- *Urban Storm Drainage Criteria Manual Vol. 3 – Best Management Practices*. Urban Drainage and Flood Control District, Denver, Colorado. September 1999.

  Denver's Urban Storm Drainage Criteria Manual provides water quality management guidance for local jurisdictions, developers, contractors, and commercial and industrial operations. This manual includes discussions of water quality principles and hydrology; in-depth selection and design criteria for a number of BMPs; standard engineering details; operations and maintenance guidelines; and BMP design worksheets. The manual is geared toward semi-arid climates

- ASCE Database www.bmpdatabase.org

1.13 INITIAL MEASURES AND MINIMUM PRACTICES

The Level of Service Method described in Chapter 6 of this manual is detailed and flexible enough for a wide variety of sites and development types. Additionally the following BMPs are important in a comprehensive stormwater management program and should be considered and utilized whenever possible in conjunction with the level of service method:

- Preserve natural systems
- Introducing community-wide stream buffer systems through enactment of stream setback ordinances
- Applying soil protection and reconstruction to residential developments
- Capturing runoff from all impervious surfaces in non-residential developments using bioretention areas
- Discouraging or eliminating direct connections of impervious areas to storm drains.
- Regulating commercial and industrial "hot spots."

Descriptions of these minimum practices follow. (General siting and design guidance are discussed in Appendices A and B and detailed design specifications for each of these measures are included in Appendix E.

1.13.1 Natural Systems Preservation

Natural streams provide numerous water quality, ecological and quality of life benefits. Protection through conservation and preservation of natural streams is a national environmental objective as set forth in the Clean Water Act. Streams and their associated wetlands provide critical habitat for plants and wildlife, water quality treatment and improved infiltration of rainfall, which lessens flood impacts, recharges groundwater and preserves baseflow. Natural Streams provide recreational and open space in communities, improve aesthetics, provide natural landscapes and enhance adjacent property values. Stable steams in nature maintain a shape and plan, profile and section that most efficiently transport the water and sediment supplied to them. The geometry and processes of natural streams involve unique terminology and concepts not common to engineered channels or pipe systems. Common features of stream geometry and characteristics are presented in Figures 5.1.4.1A&B in Appendix F. Certain definitions are contained in the Section 1.6 *Definitions*. More complete information regarding the character and function of natural streams is given in Interagency (2001).

Guidance on stream protection is given in Wegner (1999), National Academy of Sciences (1999), and Heraty (1995). Natural streams should be preserved as systems and not segmented on a project-by-project basis, as the frequent intermixing of natural and man-made systems tends to degrade the function of both.

1.13.2 Hydrology Controls for Channel Protection

Urbanization in the absence of stormwater management causes many stressors to the natural channel system. The channels respond to the stressors (flow volume increases, shortened times of concentration, longer peaks, flashier flows, and lowered baseflow) by altering width, depth, velocity, suspended loads, meander radius, wavelengths and pool and riffle. Avoiding significant changes in flow volume, rate and time of concentration, reduces the likelihood of major changes in stream form.

Flow volume, rate and time of concentration control include practices, which encourage infiltration, evapotranspiration, extended detention or retention and the establishment of an induced or artificial baseflow. A successful strategy would require limitations on flow rate, duration and magnitude of post-development discharges at a number of discharge points, including common storms such as the 100% storm. The tail of hydrographs would probably need to mimic groundwater base flow. The cumulative effect of multiple detention/retention structures on duration of high flows would have to be considered. The impact of large impoundments or retention lakes on trapping sediment and interrupting sediment transport would also have to be considered. Volume control for channel protection would likely require significantly different control requirements than traditional detention practices that focused primarily on flood control from extreme events (1% storm).

This manual sets out practices and guidance to address many of these factors and reduce the impact of development on the receiving streams.

1.13.3 Stream Buffers

The "riparian zone" (the heavily vegetated band along the fringe of a stream) is an integral part of the stream system. For example, preservation of a 100-foot riparian buffer—only about 5 percent of the land in a typical watershed—can yield disproportionate benefits. This buffer limits development in the floodplain and controls streambank erosion; it removes pollutants from adjacent properties; and it can serve as a greenway park (Haag, Mazzeo, and Schulte 2001). Buffers also provide financial returns to communities—research indicates that a comprehensive system of stream buffers that typically takes up about 5 percent of a community's developable land may increase adjacent property values by as much as 33 percent (Chesapeake Bay Foundation 1996).

Columbia's stream buffer ordinance may be found in Chapter 12A of the City Code of Ordinances.

1.13.4 Soil Preservation

An important measure to protect water quality is soil protection and restoration on all residential developments. Both stormwater runoff volumes and water quality are heavily influenced by infiltration capacity (USDA 1986; Claytor and Schueler 1996). Preserving the soil's capacity to infiltrate precipitation is a relatively inexpensive non-structural measure that can be implemented as part of a development's sediment and erosion control program. Credit can be taken in the Level of Service Method for this practice.

Urbanization shortens a watershed's response to precipitation mainly by reducing infiltration and decreasing travel time. An impervious surface decreases travel time by preventing infiltration and speeding runoff, and should be limited as much as is practical. However, most urban areas are only partially covered by impervious surfaces, and the soil remains an important factor in producing runoff. Natural infiltration rates to underlying soils are primarily influenced by soil type and by plant cover. Any disturbance of a soil profile by mixing native soil profiles, introducing off-site fill materials, and increasing soil compaction can significantly change infiltration characteristics (USDA 1986).

Restoring infiltration characteristics of the entire soil profile in residential areas (and other developments) after disturbance will also benefit water quality. These requirements can help residential developments maximally infiltrate stormwater for given vegetation and cover types without structural treatment measures. A detailed soil protection and restoration specification is in Appendix E.

1.13.5 Bioretention

Stormwater runoff from impervious surfaces in non-residential land uses (commercial, office, and manufacturing) should be treated. These land uses generate more impervious surface than residential developments and this significantly impacts a community's water quality. Impervious area for residential land uses typically ranges from 12 to 65 percent, while industrial and commercial areas may include 72 to 85 percent impervious area (USDA 1986). Because most pollutants originate from atmospheric deposition, impervious surfaces are the major source of stormwater pollutants in urban areas (Claytor and Schueler 1996).

Communities can significantly impact their water quality by treating runoff from non-residential impervious surfaces such as rooftops and parking lots. Treatment of runoff from all new impervious surfaces by using bioretention areas (vegetated depressions designed to collect and treat runoff from the Water Quality Storm through an engineered matrix of soils and plant roots) is an effective and efficient practice to remove pollutants from stormwater runoff and to increase the time of concentration. Effective bioretention cells typically require only about 5 percent of the total impervious area. They are easily designed and planned as part of the site's required open space. In practice, these units are maintained in the same manner as decorative landscaped beds—minimizing maintenance costs and increasing value-added benefits. Implementing this one standardized practice in all developments can minimize design, inspection, and maintenance costs.

This practice can be utilized (and is encouraged) in the Level of Service Method prescribed in this manual (Chapter 6).

Detailed construction guidance for bioretention is in Appendix C.

1.13.6 Eliminate Direct Connections

Direct connections include downspouts and sump pumps which flow directly onto pavement or which are piped into stormwater inlets. If this water is allowed to flow over pervious surfaces, some of the water will infiltrate. This measure requires close attention to site drainage patterns to minimize associated problems such as soggy yards.

1.13.7 Regulate “Hot Spots”

Land uses that contribute greater concentrations of hydrocarbons, metals, and other pollutants are called “hot spots” and may require additional measures to manage the quality of their runoff (Claytor and Schueler 1996). Industry-specific BMPs should be employed on these commercial or industrial hotspot activities. Chapter 6 includes management practices for various land uses (adapted from the City of Portland, Oregon [2002]).

1.14 REQUIREMENTS OF OTHER AGENCIES

Rules and regulations of other agencies also pertain to drainage systems, which may or may not compliment these criteria. When conflicts are encountered, the more stringent criteria shall govern.

The following agencies have jurisdiction over streams and/or drainage systems and often require permits. Other regulations, permits and requirements may not be limited to these agencies.

- Federal Emergency Management Agency (FEMA)
- U S. Army Corps of Engineers
- Missouri Department of Natural Resources
- Other Municipal Ordinances (Flood Plain Development Ordinance, Stream Buffer Ordinance, and Erosion Control Ordinance)

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